TOWARDS A COMPREHENSIVE MODE]. OF CORONAE FORMATION ON VENUS; Suzanne E. Smrekar and Ellen R, Stofan, California Institute of Technology, Jet Propulsion Laboratory, MS 183-S01, Pasadena, CA, 91 109; ssmrekar@cythera.jpl.nasa.gov.

Coronae arc roughly circular volcano-tectonic features that arc interpreted as a manifestation of small-scale upwelling [e.g. 1,2] and arc unique to Venus. The topographic expression of coronae is highly variable, ranging from domes to plateaus, with or without moats or single or multiple outer rises [3]. Two out standing questions in the study of coronae arc how the full range of Topographic profiles arc produced and the relationship between topography and the annulus of fractures that characterize coronae. Domes, plateaus, and outer rises can be formed by thermal relaxation of a topographic high due to a rising and cooling of a hot upwelling [4-7], but interior depressions, isolated rims, and inner highs with rims, troughs and outer rises, can not. Relaxation can produce fracture annuli, but observed annuli frequently do not occur on the outer rise, as predicted by relaxation models [5,7]. A new model of upwelling is presented that can produce nearl y the full range of observed topographic morphologic and commonly observed off-set between tectonic fracture annuli and the outer topographic rise. The cold lithosphere at the edge of the plume head is sucked downward until the thermal anomaly dissipates, explaining the limited subduction qualities of some coronae [8,9]. This model differs from past approaches to corona formation in the use of temperature-dependent rheology and the prediction of pressure-release melting. Other aspects that may be key to the development of certain coronae topographic features arc the presence of a low-density depleted mantle layer beneath the high viscosity thermal lithosphere and the cooling of the thermal lithosphere during upwelling. This approach could provide constraints on thermal history.

Model Description. An axisymmetric finite difference scheme is used to model temperature and chemistry variations and a penalty function finite element formulation is used to solve the buoyant viscous flow equations [10]. The finite element grid is 90 by 90 elements; the finite di fference grid has t wice as many elements. The element spacing is non-uniform to give maximum resolution in the axial upwelling region and in the region where the plume interacts with the lithosphere. The surface temperature is $500°C$. The base of the thermal lithosphere is defined as the $1100°C$ contour. In some models, a low denisty layer of mantle residuum is included beneath the thermal lithosphere. The mantle temperature is $1300°C$. Viscosity is based on a dry olivine flow law and is scaled to 10^{21} Pa s at mantle temperature. The viscosity is allowed to vary by a factor of 100 both at higher and lower temperatures, so that the viscosity varies within the temperature range of approximately $1150°C$-$14500C$. The dimensions of the grid arc 800 km in radius and 400 km in height. The upwelling is allowed to arise from a heated region at the base of the computational domain. A radial, gaussian temperature distribution with a peak temperature of $1750°C$ is used to initiate the upwelling. This upwelling cools such that the peak temperature when the plume encounters the lithosphere is less than $1400°C$. A similar modeling approach for venusian hotspots is described more full y in Smrekar and Parmentier [11].

Model Results. The evolut ion of the topography is shown for one upwelling model (Figure 1). In this model, the plume is allowed to form and rise for 50 my. After this point the hot region is turned off, but the plume tail continues to rise for - 25 my. The thermal lithosphere is initially 50 km thick. A chemical variation is also included, in which the depletion decreases from 20% at the surface to 0% at SO km (i.e. it is contained within the thermal lithosphere). Over the time span of the calculation, 172 my., the thermal lithosphere thickens to -110 km. In this model, the plume begins to interact with the lithosphere at about 56 my. (cur ve a in Figure 1). The plume tail is no longer feeding the plume by 79 my. (curve b), The lithosphere begins to thicken at the edge of the plume head as the plume spreads laterally, driving flow outward and downward, In **curve c,** the plume is still spreading, but the thermal anomaly is less than $50°C$. The cold, dense sinking lithosphere sucks the topographic surface downward. By 116 m. y. after the start of the calculation, the thermal anomaly in the plume has dissipated (curve d). Once the thermal anomaly is gone, the thinned lithosphere at the center begins to sink. The viscous flow pattern and temperature distribution for this time step is illustrated in Figure 2. At 135 my. (curve c) the thermal lithosphere at the outer edge of the region is -100 km thick. As the cold lithospheric blob continues to sink into the mantle, the viscous flow sucks the delaminating region in towards the center (curves f and g), leaving a topographic depression in the center.

Discussion. This model illustrates a new mechanism for trench formation at coronae. Rather than being a purely viscous relaxation process, the topography is sucked downward above a sinking region of cold lithosphere. This sinking is driven initially by the viscous flow at the edge of the plume head and is sustained by the density difference between the lithosphere and mantle and the

difference in the thickness of the lithosphere above the plume and in the cooling lithosphere. When the cold lithosphere thermally equilibrates, the topography rebounds. This limited sinking of the lithosphere explains the subduction-like qualities of some coronae. In other models in which there is a larger layer of low density depleted mantle, the low density layer is pulled downward with the cold lithosphere. When the thermal anomaly dissipates, the low density regions rebounds isostatically, forming a ring of high topography that is offset from the moat. These variations in the location of the topography illustrate how the fracture annuli can be offset from the final topography. The combination of a thin but cooling lithosphere may be essential to the formation of at least some coronae topographic morphologies, as well as to the initiation of delamination. The presence of a depleted chemical layer may be required to produce an isolated topographic ring, such as seen as Heng-o Corona. This modeling approach may be able to provide constraints on the thermal and chemical structure of the lithosphere by determining the requirements for certain coronae planforms. Since lithospheric cooling may be required to form features such trenches, this represents a potentially powerful tool for interpreting tectonic history. Future work will include matching volcanic volume estimates, scaling the models to smaller coronae, and examining the effects of plume and lithospheric parameters.
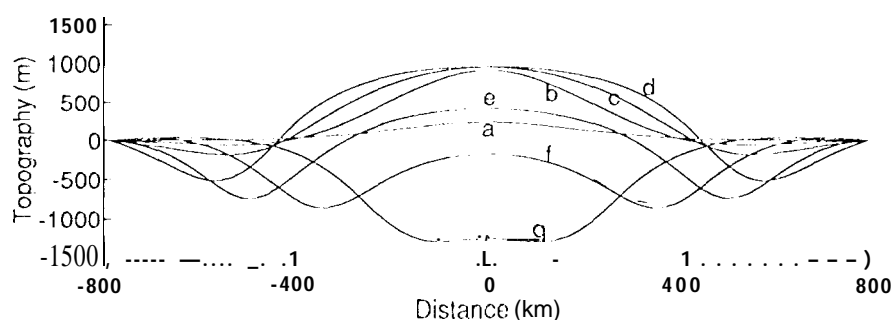

Figure 1. Predicted topography at different time steps. See text for discussion.
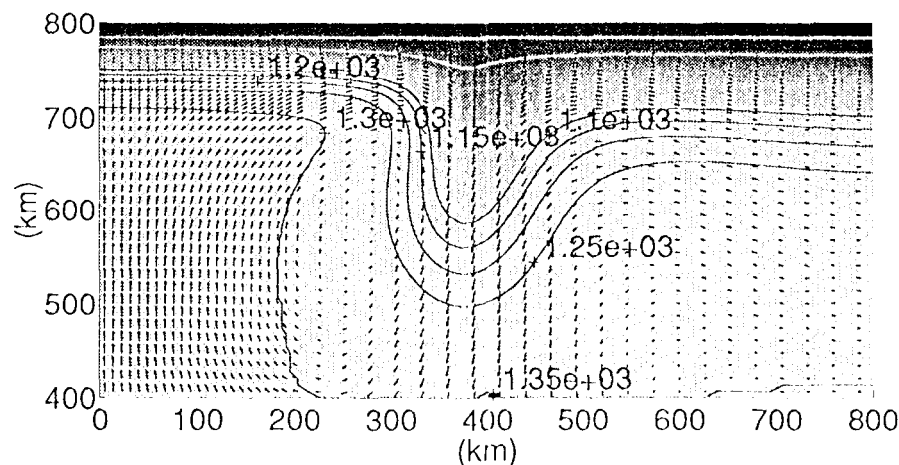

Figure 2. Computational grid that corresponds to the topographic curve d in Figure 1. Shading indicates temperature, with colder regions in darker shades. Some temperature (°C) contours are also shown in with black lines. White lines are for S and 10% depletion. Arrows show viscous flow.

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